Workscape Explorer: Using Group Dynamics to Improve Performance

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Abstract
Analyses of physical human behavioral data measured using wearable sensors have revealed that face-to-face interaction plays an important role on group performance. We have developed a web application that captures face-to-face interaction among employees as measured using wearable sensor badges and that provides persuasive feedback which encourages managers to try and change employee behaviors so as to improve business performance. Testing of this “Workscape Explorer” application in a call center environment revealed that it has a significant effect on improving employee performance.

Author Keywords
Wearable sensor; face-to-face interaction; group dynamics; groupware design.

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation (e.g., HCI): Group and Organization Interfaces–computer-supported cooperative work, evaluation/methodology, J.4 Social and Behavioral Sciences.

Introduction
Group dynamics has been quantitatively analyzed using a rich trove of human behavioral data reflected in sent e-mail logs, mobile phone location logs, social network

Figure 1. (a) Sensor badge and (b) telemarketer wearing the badge.

Exp.		C.C.	TMs
1	18 Nov.– 16 Dec. '11	A	31 female 20 male
2	7 Feb.– 9 Mar. '12	B	49 female 30 male
3	9 Aug.– 10 Oct. '12	B	85 female 54 male
4	9 Aug.– 10 Oct. '12	C	64 female 36 male

Table 1. Experiment details.

site activity records, and/or face-to-face interaction data measured using wearable sensors [1,2,3,5]. These analyses have revealed human behavioral patterns that affect group performance [6] and have facilitated the development of groupware that makes use of such behavioral patterns to improve group performance [4]. However, the effects of using group behavioral patterns as a principal design strategy for a groupware application designed to improve business performance have not been sufficiently evaluated.

We had employees in call centers wear sensor badges and examined the relationships between their physical behaviors and their performance. Our results revealed that face-to-face interaction during breaks affects their performance. We then developed a web application based on this finding and evaluated its effect on call center performance.

Sensor Badge

The badge-shaped wearable sensors (Fig. 1 (a)) we developed are for use in measuring physical behaviors. Data on the wearer's physical movements are captured by a three-axis MEMS (micro electro mechanical system) acceleration sensor and are used to detect individual activities. Six IrDA (infrared data association) transceivers on the front of the badge and facing different angles are used to detect face-to-face events. They can transmit and receive signals up to a distance of 3 m within a 15° cone. Two face 15° leftward horizontally, two face 15° rightward horizontally, and the other two face forward and 30° downward. With this alignment, the overall detection range is 60° horizontally and vertically, which should cover virtually any face-to-face interaction in an office environment. By using user IDs linked to each badge, information can be obtained about who met whom, when, and for how long. The captured data are stored in built-in 32-MB flash memory and offloaded for database transfer while the badge is in the charging cradle overnight. The badge is light and small enough to be hung from one's neck during working hours (86 × 54 × 7 mm, 34 g). The battery lasts about 24 hours between charges.

Location information is also obtained using IR beacons set at particular places such as in a smoking area, a break room and the official meeting space.

Experiment

Targets

We targeted three "outbound" call centers. Employees call potential customers in an effort to sell them a product or to get them to contract for a service. A person making such marketing phone calls is called a telemarketer (TM). The three call centers, Call Centers A, B, and C are located in west, northeast, and central Japan, respectively. We conducted a total of four experiments (Table 1). In Exps. 1 and 2, the TMs marketed an Internet TV service. In Exps. 3 and 4, they marketed two different types of Internet services. We measured the physical behaviors of the TMs, supervisors (SVs), and managers by having them wear sensor badges (Fig. 1 (b)). We placed IR beacons at all their desks to enable us to detect when they were at their desk working and when they were away from their desk resting.

Measures

The physical movements of the TMs were captured using the acceleration sensor in the badges they wore. The zero-crossing count, defined as the number of times the acceleration signal crossed the zero-level per unit time, was used to determine the activity level: the higher the count, the more active the TM's bodily movements. Each TM's activity level was judged to be in one of two states, active or non-active, every minute in accordance with the zero-crossing count. The threshold value for the count was set to 2 Hz on the basis of the results of a preliminary study, which showed that it was the level at which active motion such as conversation with gestures could be distinguished from quieter motion such as keyboard typing. Therefore, the activity level for a minute during which the zero-crossing count was greater than 2 Hz was judged to be in the active state, otherwise it was judged to be in the non-active state.

We then defined the activity level of the entire call center as;

$$\text{Group Activity Level} \equiv \frac{\sum_i M^i_{Active}}{\sum_i M^i_{All}}, \qquad (1)$$

where M^i_{All} is the total number of minutes TM_i was in a defined period (e.g. total minutes he or she was at desk working, or away from desk resting during a day) and M^i_{Active} is the total number of minutes TM_i was judged to be in the active state during that period. Hereafter, we call the value calculated in eq. (1) the "group activity level," or GAL for short. The GAL took a value of 0 to 1, where a higher value means that the call center was more active.

Exp.	C.C.	GAL	
		Working	Resting
1	A	−0.11	**0.38****
2	B	0.28	**0.37****
3	B	0.25	**0.53*****
		0.25	**0.72*****
4	C	**0.45****	**0.41***
		0.05	**0.38****

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2. Correlation coefficients between daily GAL and daily call center performance. In Exps. 1 and 2, they marketed an Internet TV service. In Exps. 3 and 4, they marketed two different types of Internet services.

Their face-to-face interactions were captured using the IrDA transceivers in the badges. We interpret that two people interacted with each other if there was a face-to-face event between them exceeding a predefined threshold. We defined the threshold as 3 minutes per day, and counted the number of people with whom each TM_i interacted as *degree*, k_i. The larger the k_i, the more actively he or she interacted with others.

As a measure which represents call center performance we used "the number of orders received per hour," which is the number of products a TM sold per hour.

Results

We found that daily call center performance (i.e., the average performance of the TMs working each day) correlated significantly with the daily GAL while resting. Whether they were at their desks was determined from the data collected by the IR beacons on their desks. That is, if there was no face-to-face event between a sensor badge and an IR beacon at the desk, the TM wearing that badge was not at the desk working but on a break, resting. As shown in Table 2, this correlation was observed in all experiments. In contrast, the daily GAL while working was not correlated with the daily call center performance for the experiments (except for one of the two products in Exp. 4).

We examined the causality: does GAL affect performance or does performance affect GAL? Our trial letting TMs take breaks at the same time changed their ways of communication during breaks. We observed significant increase in their average *degree*, GAL, and performance. This indicates that face-to-face interaction during breaks affects GAL, which in turn affects the performance.

Workscape Explorer

We then developed a web application for managers and SVs named "Workscape Explorer" (WSE) that provides feedback on face-to-face interaction, GAL, and performance. Both the behavioral data and daily business performance data of each TM are transferred to the server overnight and analyzed automatically by a Java Servlet 3.0 application on the server. It calculates the daily GAL while resting, the daily face-to-face interaction indices k_i, and the daily average performance of the call center.

A screenshot of the main WSE page is shown in Fig. 2. WSE runs on the Google Chrome browser. Daily business performance and GAL are represented in the graph labeled (A). Data for two weeks are plotted. A manager can quickly grasp the trends in business performance and GAL by viewing the graph.

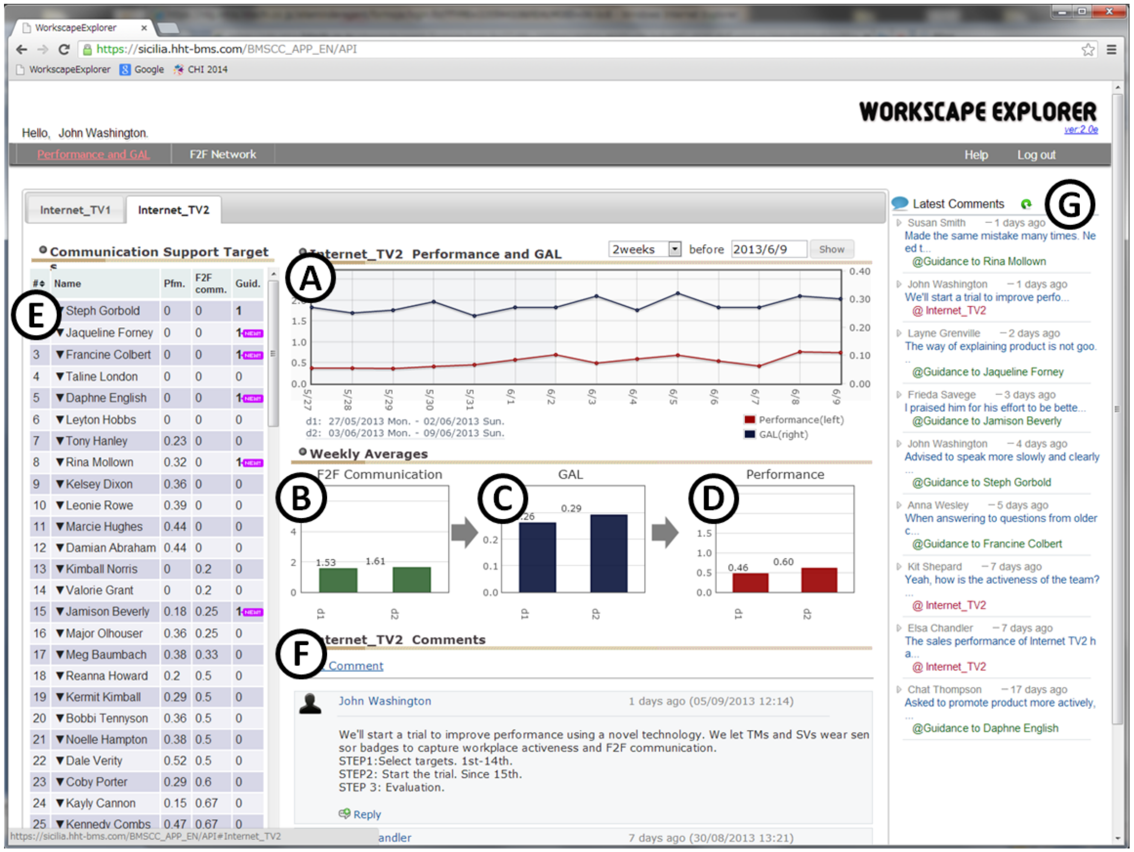

Figure 2. Screenshot of main WSE page.

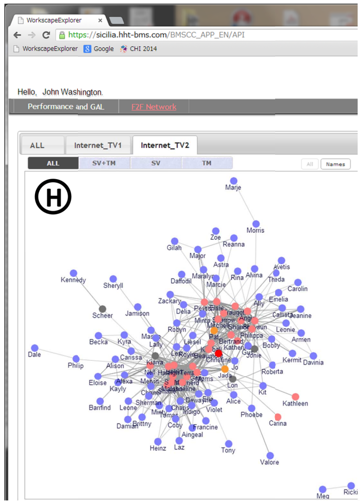

Figure 3. Screenshot of face-to-face network diagram page of WSE.

We show these two values for the first (d1) and second (d2) weeks on the bar graphs labeled (C) for GAL, and (D) for performance. The average *degree* is likewise shown on the one labeled (B). These three bar graphs were arranged from left to right to represent our design principle: face-to-face interaction affects GAL, and GAL affects performance. These visualizations from (A) to (D) implement the strategy for improving call center performance: continuously monitor not only performance data but also GAL during breaks, and face-to-face interaction among employees.

The names of all the TMs are listed on the left of the main user interface, in a "Communication Support Targets" listing (E). The default ordering is as follows. The names are first sorted by performance (Pfm), with the lowest performance at the top. They are then sorted by face-to-face interaction index k_i, with lowest *degree* at the top. This enables the managers to focus on the TMs with the worst performance and the least amount of interaction. The "Guid." column shows the number of comments posted for the TM by the SVs or managers. Detailed information about the trends for a TM in terms of performance, face-to-face interaction, and posted comments can be obtained by clicking on the TM's name, which causes the display to jump to an individual page. This "Communication Support Targets" list is used by managers or SVs to find TMs who should be appropriately supported.

Our finding in all four experiments that the GAL during resting affects group performance indicates that this effect goes beyond call centers and the products they sell. We added a social-network-like function to WSE (F) that promotes information sharing and decision making in call centers. Managers can post comments and messages regarding, for example, the content of trials for improving performance or guidance for individual TMs. The posted comments concerning the entire call center, for example, announcement of a trial starting, are shown on the main page. The comments for an individual TM are shown only on that individual's page, not on the main page.

A manager can browse all the comments in the "Latest Comments" list (G) on the right, where comments are listed with the latest at the top. They can thus view the temporal trend of the comments, which should help them design techniques and strategies for changing TM behavior and improving performance.

Another page in WSE presents a face-to-face network diagram that enables managers to quickly grasp the group's face-to-face interaction situation ((H) in Fig. 3). It represents face-to-face interactions among TMs, SVs, and managers per day, averaged over the period defined on the main page (default is latest two weeks). Each node represents a person: TMs are blue, SVs are pink, managers are orange, general manager is red, and others are gray. Links are drawn if there was a face-to-face event between two people for a length of time exceeding a predefined threshold.

This face-to-face network is drawn using the spring model, in which nodes with more links are located closer together while those with fewer links are located further apart. Therefore, people located at the edge of the network have less interaction with the others and could be candidates for guidance by the SVs and managers. This network also makes it possible to discover a "hub" person, someone who may be a hidden group leader.

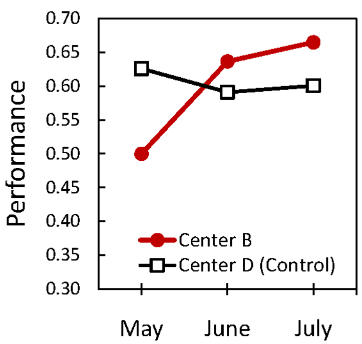

Figure 4. Effect of introducing WSE.

Evaluation

WSE was launched for Call Center B on 27 May 2013. This call center had 110 TMs (81 female, 29 male) and 28 SVs at the time. Immediately after introducing WSE, the call center manager started using it to design a trial for improving the GAL of his teams. He then announced the trial by posting a comment in field (F):

"We have started using a new business system using wearable sensors. A trial to improve GAL so as to improve performance will start on 3 June."

The following week (27 May to 2 June), he selected 12 TMs (*targets*) who had lower performance and less face-to-face interaction by using the "Communication Support Targets" list (E) and the face-to-face network diagram (H). He also selected 7 TMs (*supporters*) who had higher performance and more interaction in the same way. In the trial, the 7 supporters were asked to actively communicate with the 12 targets during their breaks, particularly in the break room.

As shown in Fig. 4, we found that performance of Call Center B increased significantly after the trial started, from 0.49 in May to 0.63 in June on average ($p < 0.0001$). To identify other factors that might have caused the increase in performance in June, we compared the performance with that of another call center located in a different town (Call Center D) that sold the same product. Their average performance in May was 0.62, and that in June was 0.59, and there was no statistically significant difference between them ($p > 0.34$). This indicates that the increase in performance in Call Center B was not caused by a seasonal factor. Call Center B conducted the same trial in July with other 11 targets. The performance in July continued to increase, reaching 0.66 on average, which was significantly higher than the performance of Call Center D in July (0.60, $p < 0.05$).

Discussion and Conclusion

The results of our experiments demonstrated that business performance can be improved by using WSE, which consists of wearable sensor badges employees wear, IR beacons distributed in the environment, a server-side application for data analysis, and client applications for visualization and feedback of group dynamics. Regarding the functions implemented in WSE, the managers and SVs were quite positive about using them. We received many positive comments in particular for the face-to-face network diagram visualization function, which was useful for designing trials for improving workplace communication. Future work includes introducing WSE to several call centers and enhancing its functionality to make it useful for multiple call center operation.

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